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Improved BIFV Troop Compartment Visibility: Development of a Transparent, Bullet-Proof Dome

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At present, personnel within the Bradley Fighting Vehicle's troop compartment must use a set of vision blocks (periscopes) while performing close-in local security checks, Forward Observer tasks, passive air defense, and battlefield reconnaissance prior to dismount. Use of a transparent cargo hatch cover was looked at as a way to enhance combat effectiveness and morale. A prototype was subjected to limited feasibility testing and the results support the conclusion that combat effectiveness is facilitated by the transparent cargo hatch cover. Troop compartment personnel reacted positively to replacement of the present cover with the transparent cargo hatch cover. Recommendations for refining the concept include a two-man bench seat for use with the cover, an interior cover for proper light discipline, and procedures for reducing light reflection to a minimum.

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FOREWORD

Since 1975 the Army Research Institute for the Behavioral and Social Sciences (ARI) has contributed to the U.S. Army program to develop Bradley Infantry (M2) and Cavalry (M3) Fighting Vehicles, with human factors evaluation of prototype vehicles and analyses of crew tasks to identify special aptitude requirements. Task analysis resulted in a set of Procedures Guides for Bradley Commanders, Gunners, and Drivers; identification of leader tactical training device requirements; and recommendations for a Bradley Leader Tactical Trainer.

As Bradley vehicles were introduced to combat units, the need to evaluate tactical doctrine, operational effectiveness, and training issues in a systems context became apparent. At the request of the Deputy Chief of Staff for Training, U.S. Army Training and Doctrine Command (TRADOC), a research program was formalized among the Training Technology Agency, TRADOC, the U.S. Army Infantry School, and the Army Research Institute to define emerging operational and training problems and to undertake research to address the most critical issues affecting combat effectiveness. Because Bradley vehicles incorporate advanced weapons systems and sights to be used in darkness and reduced visibility, special emphasis was placed on that research focused on operations under these conditions.

The first year of the project resulted in definition of critical research issues and identified gunnery, tactical operations, equipment, and training as topical areas for subsequent research and development. The problem identification and supporting analyses are presented in a separate report.

The results of the second year of research are documented in a series of publications of which the present report is one. The emphasis of the second-year effort was on making products available to Bradley users as they were developed. These analyses, training materials, job performance aids, improved procedures, and equipment prototypes have immediately increased combat effectiveness. Further interactions between the project scientists and the user community have resulted in additional improvements and refinements. As a result of this approach, the project has been unusually responsive to both the U.S. Army Infantry School and Bradley units worldwide.

IMPROVED BIFV TROOP COMPARTMENT VISIBILITY: DEVELOPMENT OF A TRANSPARENT, BULLET-PROOF DOME

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PROBLEM DEFINITION

The Bradley represents a vast technological advance over the previous armored personnel carrier (M113), and this gives the Army greater capability to perform many conventional mechanized infantry tasks better and to utilize this sophisticated weapon system in many new ways. However, the research team noted very early that the advanced design of the BIFV actually created some issues that were not an area of concern with the M113. Three of these issues relate to the difference between the completely open hatch design of the M113 and the enclosed troop compartment of the BIFV. These issues are: (a) local security; (b) passive air defense; and, (c) motion sickness and claustrophobia. Therefore, an improved system of providing a view of the battlefield from within the troop compartment was selected as an area for investigation during the second year of the project, because one solution could potentially address multiple issues.

Additional impetus to selection of this area for further work during the second year of the project was provided by a request from the Director of the Department of Training and Doctrine and the Combined Arms and Tactics Department of the U.S. Army Infantry School, that ARI/Litton investigate alternative approaches to improving troop compartment visibility. The completed work and directions for further development are described in here. Additional background defining the problem is given first.

Visibility to Flanks and Rear

Personnel in the troop compartment must perform a number of tasks which are dependent upon the ability to see the battlefield. These are:

- Operation of the M231 Firing Port Weapon mounted in conjuction with a vision block;
- Detection of threat dismounted infantry and mechanized targets at a distance;
- Maintaining close-in local security during halts;
- Reconnaissance of the battlefield prior to dismount.

A vision block system provides the only mode of viewing outside the vehicle when the troop compartment hatch is closed. Normal performance of the tasks listed above is highly dependent upon the degree of visibility the soldier can obtain through one of the vision blocks. In its present configuration, the troop compartment of the Bradley has seven periscopes (vision blocks) mounted two each on the right and left side of the vehicle and three on the top of the

hull facing to the rear. Each vision block is a double prism that is eleven inches in height and eight inches wide. A fifteen degree upward tilt of the prism allows greater long distance viewing.

During the unit exercises observed by the research team, the periscopes required frequent cleaning to remove dust, mud or snow and this can only be done by an individual from an exposed position outside the vehicle. Further investigation by the team produced a plot of the dead space resulting from inadequate overlap of the field of view from adjacent vision blocks (see Figure 1).

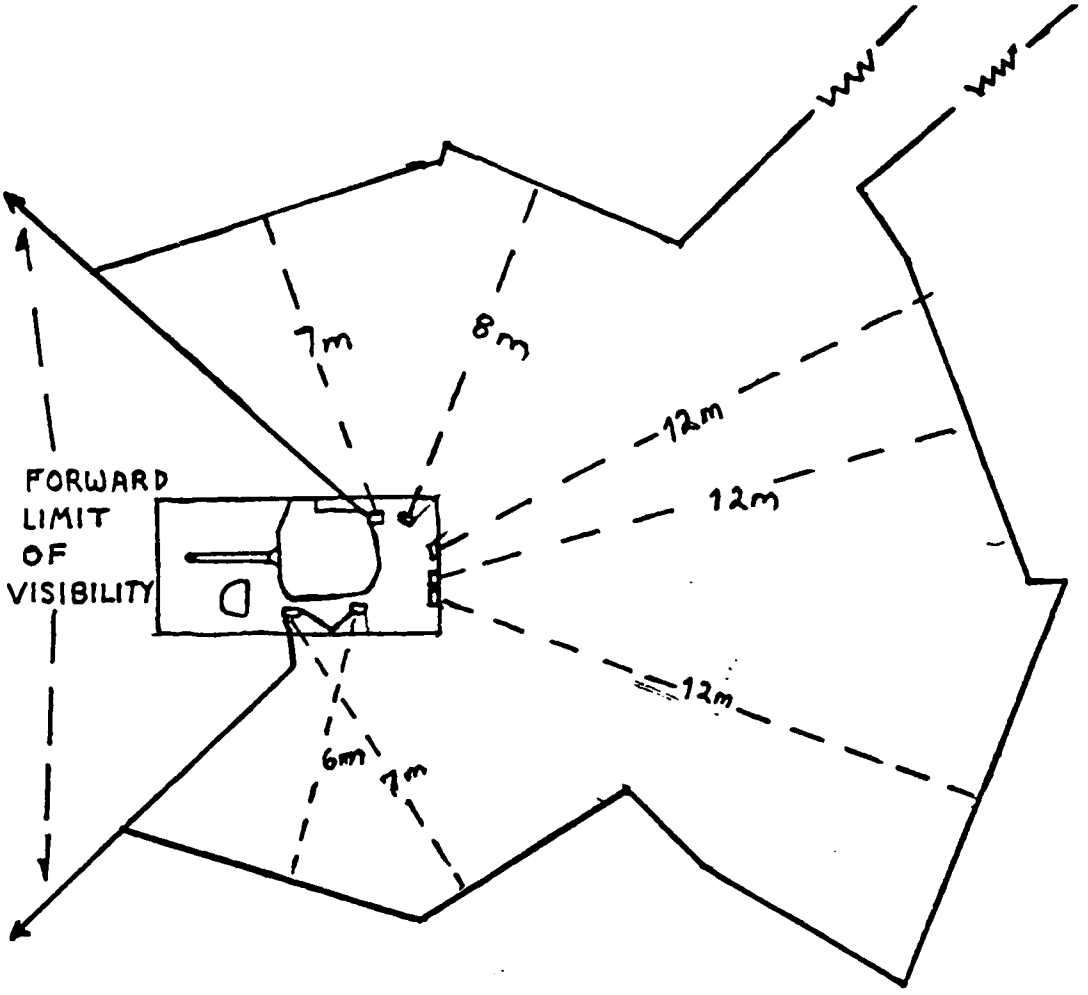


Figure 1. Approximate dimensions of BIFV ground level deadspace.

This dead space envelope was determined by moving an object out from the vehicle until it could be detected at ground level from a vision block. This exploratory test was done under daylight conditions. The figure shows that the detection distance under these conditions is 6-8 meters on the flanks of the vehicle and 10-12 meters to the rear. Additional data collection would be necessary to determine the capabilities for detection of objects at varying

heights above the ground under all visibility conditions, with and without vision enhancement devices. However, many tactical situations in urbanized or heavily vegetated environments could be envisioned, in which the dead space shown above could have disastrous consequences.

In short, the vision block system suffers from serious lack of close-in visibility at all times, and vision at a distance can become blinded at critical times by obscurants.

Overhead/Panoramic Visibility

As noted, there are additional tasks requiring a reliable means for obtaining a view of the battlefield. These are:

- Performance of Fire Support Team (FIST) and Forward Observer (FO) tasks;
- Performance of airguard tasks.

The ability to perform these functions using the current vision block system is totally limited, and current doctrine prohibits the option of placing an individual in the cargo hatch opening to perform these tasks. The turret override must be engaged for the turret to function with the hatch open and this poses a safety hazard to the individual in the hatch and the other personnel in the troop compartment. The speed and mobility of the Bradley make it difficult to maintain balance while standing in the hatch. Finally, an open hatch increases the threat to troop compartment personnel from artillery fires. At present, the commander and gunner hatches are the only positions from which these tasks could be performed. However, the primary responsibilities of these individuals preclude effective performance of FO or airguard tasks as addititional duties. The research team observed that current practice in units is to ignore passive air defense except to the degree that the Bradley commander can observe the air as part of his duties. Secondly, the FO typically rides in the troop compartment of the platoon leader's vehicle and can perform in the intended role only when it is possible for him to dismount.

Morale of Troop Compartment Personnel

In addition to noting the need for an improved visibility system in order to perform combat tasks from the interior of the troop compartment, research team observers noted a tendency on the part of troop compartment personnel to develop motion sickness and feelings akin to claustrophobia after periods of confinement in the crowded interior. The closed-in feeling is somewhat alleviated when the cargo hatch is open, but current doctrine and combat conditions will normally dictate that the hatch remain closed. A vehicle modification that provides a wider field of view without impacting on personnel safety would give the soldier a greater feeling that he is able to stay current on what is going on outside the vehicle. This should benefit both morale and the performance of tasks from within the troop compartment.

APPROACH

The research team identified candidate technologies showing potential for improving visibility from the troop compartment. Three candidates were pursued in some depth: (a) redesign or rearrangment of the present vision block configuration; (b) fiber optics relay of the ISU sight picture to the troop compartment; and, (c) development of a transparent cargo hatch cover. For each candidate, the feasibility of producing and implementing a modification of the vehicle was assessed, and the potential of each candidate modification for solving the present problems with troop compartment visibility was analyzed.

The Present Vision Block System

Manufacturers of periscope/vision block products were contacted to determine the state-of-the-art in this technological area. Present product development efforts, which could impact on the current BIFV vision block system, involve changes which increase the field of view from any one vision block and changes in mounting locations and angles to improve overlap from adjacent periscopes. Additionally, planned modifications to the M3 (the Cavalry Fighting Vehicle) involve adding vision blocks mounted in the cargo hatch cover. After determining that other agencies were pursuing approaches to improved troop compartment visibility that concentrate on modifications of the present vision block capabilities, the research team estimated the degree to which these modifications would address the problems noted in the field. The projected improvements could increase effective employment of the firing port weapon and detection of local threat to the flanks and rear of the vehicle. However, performance of FIST/FO functions, detection of the enemy air threat, and the potential for one individual (e.g., the assistant squad leader) to obtain a panoramic view of the battlefield prior to dismount, would benefit little from changes limited to the present vision block system.

Fiber Optics

Fiber optic technology offers the possibility of transmitting the ISU sight picture to a TV monitor mounted in the troop compartment. However, the ISU and turret would require modifications of significant cost to implement the technology. Additional research would be required to determine the reliability of such a system under high mobility conditions. Resolution of the monitor image to produce an interpretable picture would also require research. A means for rapid determination of the turret orientation at any given time would have to be added. After determination of the high potential cost of a fiber optic system and identification of the needs for additional research before the advantages of such a system could be established, the research team concluded that other approaches should be pursued first.

Transparent Cargo Hatch Cover

This approach was selected for further work during the second year of the project. The concept for a see-through capability, with the cargo hatch closed, specified the following requirements:

- An individual must be able to make a panoramic lateral scan of the battlefield (approximately 270 degrees,

exclusive of the area to the front obscured by the turret) without moving from his position in the troop compartment;

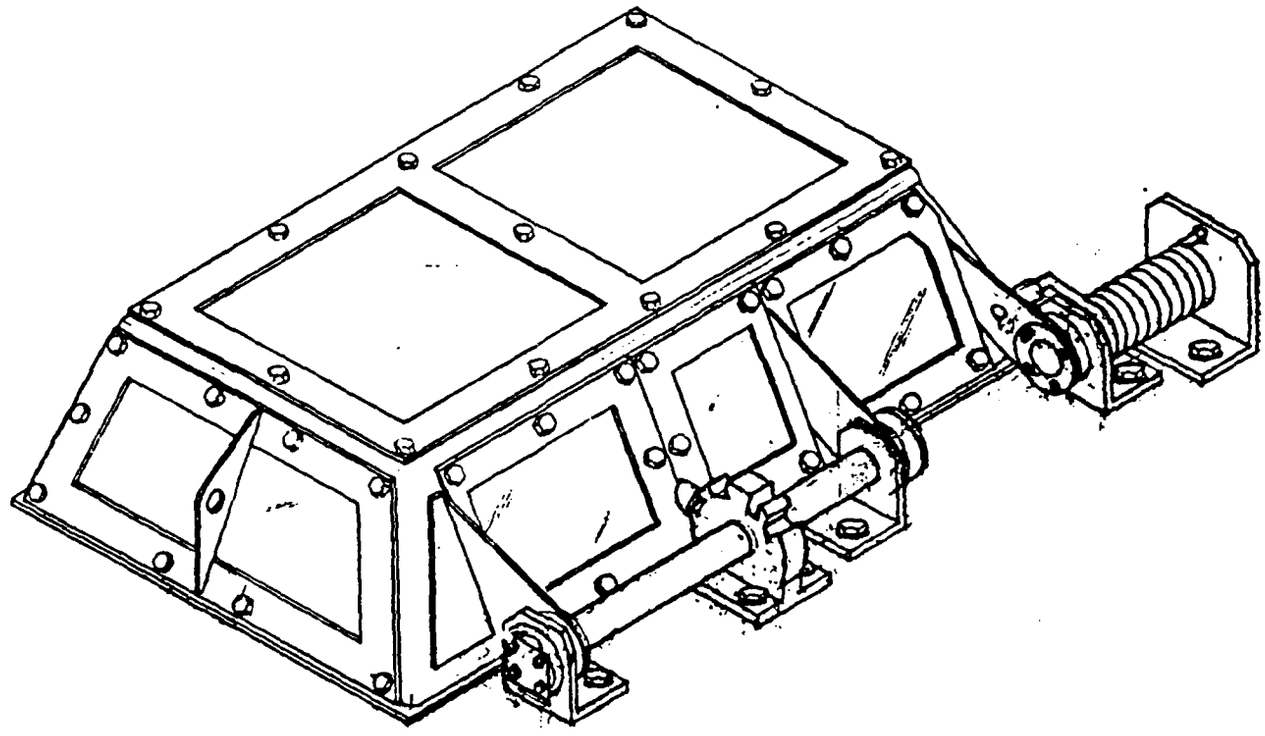
- An individual must have an unobstructed overhead view from horizon to vertical;
- The dead-space envelope must be reduced to give greater visibility close-in to the vehicle;
- The ballistic protection provided for troops must be equal to or greater than that afforded by the present aluminum cargo hatch cover;
- The design must permit replacement of current cargo hatch cover without requiring hull modification or interfering with 25mm gun barrel travel;
- The transparent viewing surface must not distort unaided vision and vision aided by magnification devices or STANO (Surveillance, Target Acquisition and Night Observation) devices, to any significant degree.

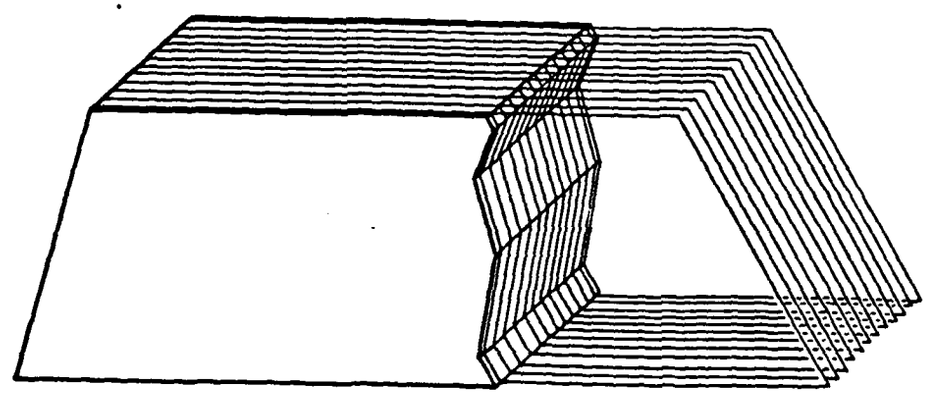
With these requirements in mind, the research team proceeded with the design of a prototype. Manufacturers of bullet-proof glass were canvased to determine the feasibility and estimated cost of transparent viewing surfaces that would meet the specified needs. Representatives of the firm, Vision Blocks, Inc., demonstrated a product consisting of 12 bonded layers of glass totalling three inches in thickness. The interior surface is laminated to prevent spalling. Distortion of visibility through the glass is less than one percent and the reflectivity of the glass surface can be reduced by 65% with the use of an emulsion spray. The weight of this product is 30 pounds per square foot.

A contract was initiated with Vision Blocks, Inc. to produce a prototype that utilized this glass product mounted in a frame meeting the specifications of the present cargo hatch cover. Manufacturers having the capability to produce such a frame were canvassed and Engineered Systems Co. was selected to fabricate the mounting for the glass surfaces. The basic shape selected was a domed frame with trapezoidal viewing surfaces. Figure 2 shows a schematic of the transparent cargo hatch cover as designed by ARI/Litton and fabricated by the contractor.

The entire assembly is 48 inches long by 30 inches wide at the base, with a center height of 12 inches above the plane of the hull. The frame is constructed of light carbon steel bolted in an arrangement which permits disassembly for replacement of individual glass surfaces as necessary. The mechanism for opening the hatch cover is a modification of the present torsion bar arrangement to accomodate the increase in weight (600 lbs versus 350 lbs) required by the added volume of frame and glass.

The prototype was delivered to ARI/Litton in October, 1985. An immediate opportunity to conduct limited evaluation of the prototype arose when it was found possible to satellite the testing to a field exercise scheduled during November, 1985. The procedures and results are described below.





Cross Section of Laminated Glass

Figure 2. Details of the transparent cargo hatch cover.

EVALUATION OF THE PROTOTYPE TRANSPARENT CARGO HATCH COVER

Procedure.

The ARI/Litton research team conducted a study of BIFV leader span of control using a three day tactical exercise as a setting. It was determined that the prototype could be subjected to trial within this setting also, with the scope of the evaluation limited to data collection that could be accomplished without interfering with the tactical focus of the study.

Permission was obtained to mount the prototype cargo hatch cover on one of the vehicles supplied for the tactical test by 1st Battalion, 29th Infantry. The BIFV assigned to the friendly force platoon leader was selected. During the exercise, the troop compartment of this vehicle carried an individual assigned to FO duties, the platoon leader's RTO, the medic, and the ARI/Litton team member performing the observer role. An observer checklist was constructed prior to the exercise that called for notation of items such as the amount and type of use, maintenance required, observed instances where the prototype transparent cover contributed to effective performance of combat tasks, and anecdotal evidence relating to user attitudes toward the modification. A post-exercise questionaire was completed by the troop compartment personnel to elicit further reactions on the advantages/disadvantages of the transparent cover.

In summary, the evaluation procedures permitted exploratory analysis of the degree to which the prototype impacted on troop compartment visiblity issues. The evaluation opportunities included a variety of tactical situations, variations in weather, alternating static and high speed maneuver conditions, and both daylight and limited visiblity situations. Data was accumulated from both a trained observer and active duty personnel.

Observations

Though the trial procedures were frankly exploratory and not designed to produce the volume of systematic data required to completely validate the concept of a transparent cargo hatch cover, useful observations on the performance of the prototype were obtained. Results bearing on the feasiblity of the concept are:

- FO tasks were performed effectively from within the troop compartment by an experienced mortar platoon member attached to the platoon command vehicle. Comments from this individual on the advantages of the cover were positive;

- Personnel in the troop compartment spontaneously commented on the increased capability for early detection of enemy air threat afforded by the new cargo hatch cover;

- Close-in dead space was reduced to within three meters (approximately), with the vehicle on level terrain;

- Inclement weather during the exercise resulted in obscured vision from the periscopes but vision from the transparent cargo hatch cover was never degraded by mud, condensation or other obscurants;

- Comments from troop compartment personnel reflected the perception that the cover reduced feelings of claustrophobia and motion sickness.

- Troop compartment personnel categorically preferred the new transparent cover to the original cargo hatch cover. However, users expressed some concerns about the concept that reinforced the awareness of the research team of the need for the following actions to further develop the concept and expedite implementation:

  (1) Design of a seat with height adjustments to provide support and eliminate cramping resulting from inability to stand fully upright when viewing through the cover;

  (2) Addition of interior opaque covers with velcro fasteners to support proper light discipline;

  (3) An information program that assures troops that the modification provides ballistic protection equal to or greater than the present metal cover;

  (4) An information program that assures troops that light reflection from the cover is manageable and will not increase the ability of the enemy to detect the BIFV.

In summary, the prototype was subjected to trial during a tactical exercise conducted in November, 1985. The results support the following conclusions: (a) effective performance of combat tasks from the troop compartment is facilitated by the transparent hatch cover; (b) troop compartment personnel react positively to replacement of the present cover with the modified cover; (c) the general feasibility of the concept is supported by the fact that all noted problems with the prototype are susceptible to solution within minimal time and cost parameters.

RECOMMENDATIONS

The limited feasibility trial demonstrated that the prototype transparent cargo hatch cover is a viable concept. The research team formulated recommendations for further work to refine the concept. Specifically, it is recommended that:

- The transparent cargo hatch cover be subjected to complete operational test;

- A two-man bench seat with height adjustment be designed for use with the cover;
- An interior cover to provide proper light discipline be perfected;
- Research and development to reduce light reflection to minimal levels be performed;
- Systematic studies be conducted to compare advantages/disadvantages of the modified cover to the present cargo hatch cover in the areas of;

  (1) Performance of passive airguard tasks,

  (2) Performance of FO tasks,

  (3) Performance of local security tasks,

  (4) Reduction of incidence of claustrophobic reactions,

  (4) Reduction of incidence of motion sickness,

- Systematic studies be conducted to determine the degree of user acceptance of the transparent cover.

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